

Subjective Suit Fit Assessment

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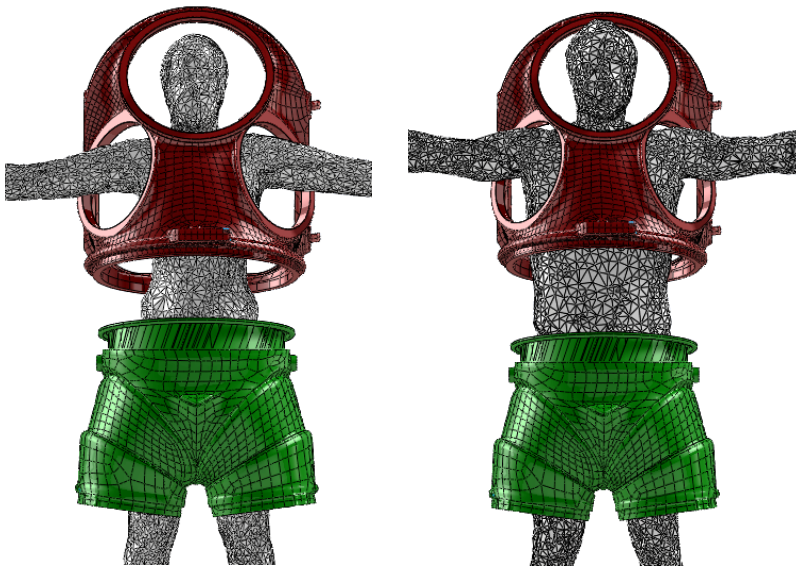
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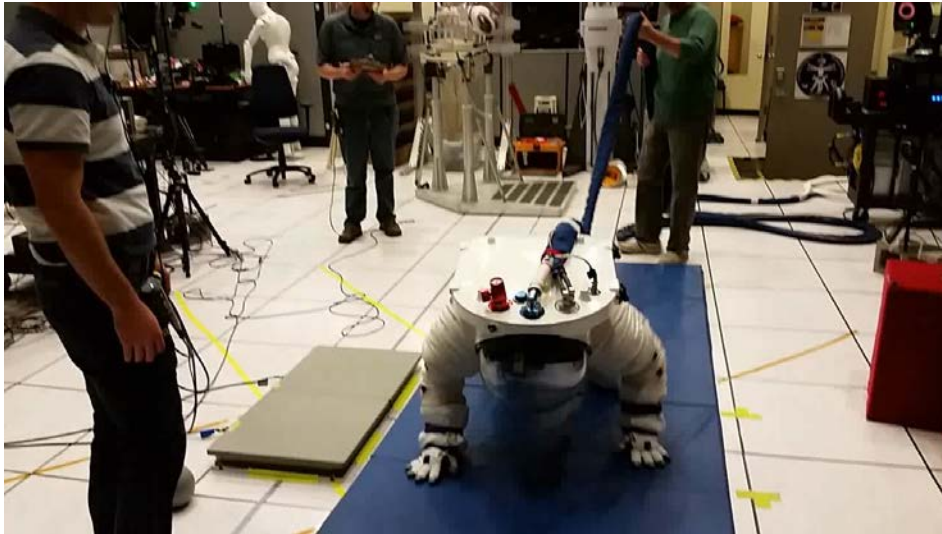
INTRODUCTION

- Current spacesuits are no longer custom fit
 - Sizing options exist, but good fit can still be a challenge
- New prototypes often come in a single torso size
 - Perfect fit for some, awful for others



INTRODUCTION

- Poor fit can affect mobility and performance
 - Free volume in the suit
 - Body bounces around in torso
 - Hands come out of gloves
 - Visibility reduced
 - Pressure points and suit impingement



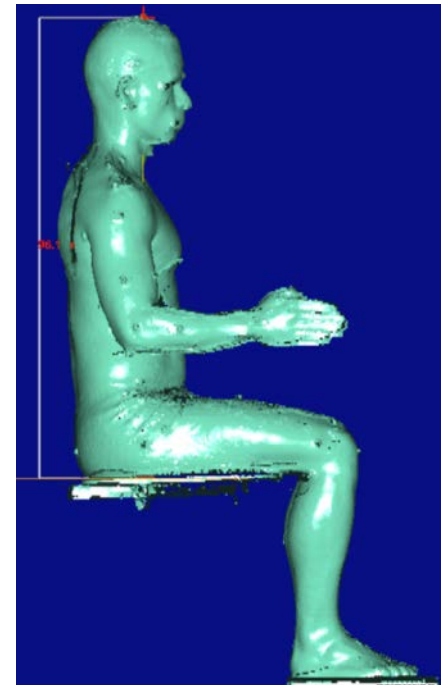
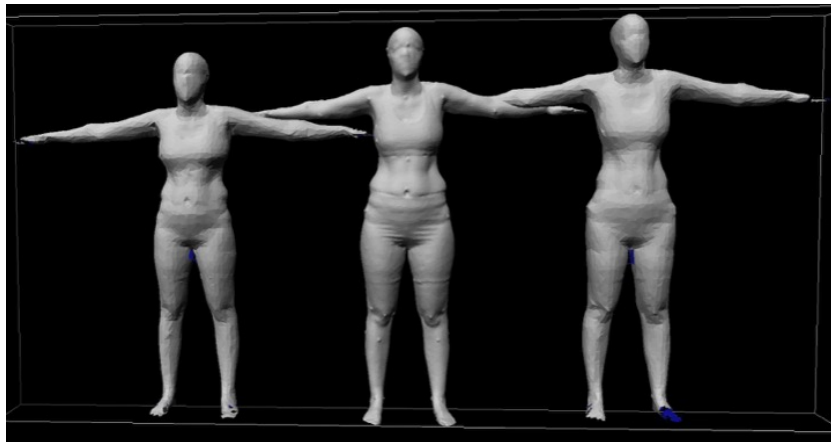
BACKGROUND

- Suit fit issues can introduce confounding factors into research data
 - Restricted range of motion
 - Subject avoids or is unable to reach where they otherwise would in a better fitting suit
 - Increased effort
 - Energy expended may be due more to fighting against an ill-fitting suit than due to suit design issues
 - Different methodologies
 - Suit programming
 - Shifting body inside the suit
- These differences may overshadow other differences in data



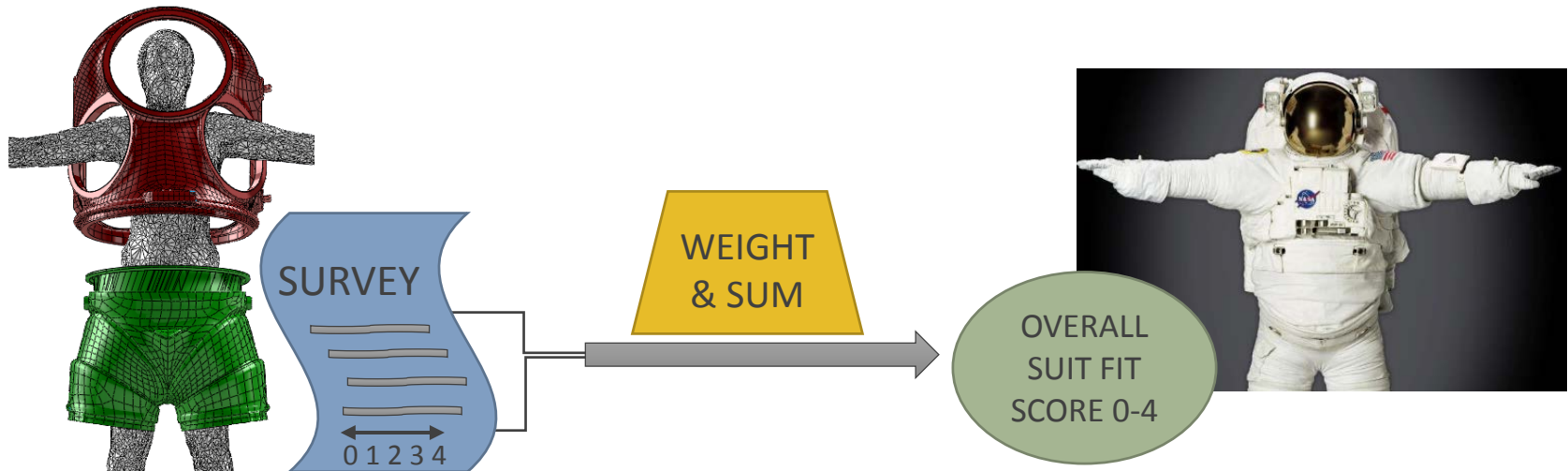
BACKGROUND

- Existing suit fit methods involve:
 - Initial suit fit check based on anthropometry
 - Adjustments based on subjective feedback
- There is no formal way to quantify and compare the quality of suit fit from one subject to another
 - Suit component sizes are recorded as well as relevant subjective comments but these are hard to compare from one person to another



GOAL

- Develop a methodology for quantifying suit fit
 - Start with a subjective survey of questions
 - Maintain consistency with use of the survey
 - Determine an appropriate method for weighting different aspects of the survey
 - Develop a scoring system such that different subjects can be compared



METHODS: Survey Questions

- Queried multiple people around the EVA community
 - Suit engineers
 - Suit technicians
 - Subjects
 - Anthropometry experts
 - Biomechanical engineers
 - Statisticians
 - Additional individuals with spacesuit experience
- Pulled questions from existing suit sizing documents used by engineers to determine the initial fit, i.e.:
 - *Do you have any pressure points?*
 - *How would you describe the volume inside the HUT?*
 - *Do you feel restrictions when attempting to extend your arms?*


METHODS: Survey Development

- Identified key aspects of fit
 - Discomfort
 - Indexing
 - Spacing between the body and the suit (i.e. tight or loose)
 - Feature alignment
 - How do the suit's features align with the body joints
 - Mobility
- Applied numerical scoring to each section
 - 5-point scale (0-1-2-3-4)
 - 0 is always ideal, and 4 is the worst case scenario
 - Word anchors only at ends of scale

DISCOMFORT

“Rate the level of discomfort you are experiencing due to the fit of the suit”

- Assessed by body region
 - Head/neck
 - Torso (upper/lower)
 - Arms (shoulder, forearm, hand)
 - Legs (upper, lower, feet)
- Severe discomfort in any area will lead to an adjustment of fit or application of padding or other countermeasures
- Suit exposure questionnaire will record any suit related trauma/symptoms separately

DISCOMFORT							
			None  Severe				
Affected Region			0	1	2	3	4
Torso	Head	L-Side	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Neck	Top	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Upper Torso	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Lower Torso	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Arms	R-Shoulder	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Shoulder	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	R-Lower Arm	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Lower Arm	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	R-Hand	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Hand	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Legs	R-Upper Leg	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Upper Leg	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	R-Lower Leg	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Lower Leg	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	R-Foot	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	L-Foot	None	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Options to indicate specific locations

INDEXING

“Rate how well you fit within the volume of the suit”

- Assessed by region of suit
 - Upper Torso
 - Brief
 - Gloves
 - Overall length
 - Field of view
- Suit sizing availability sometimes results in subjects moving forward with suboptimal indexing (often the case with single size prototype designs)

INDEXING								
				Ideal \longrightarrow Worst Case				
PART 1	HUT Indexing	Worst Position	Tight/Loose	0	1	2	3	4
	Front to Back spacing	Bending over	Neither	○	○	○	●	○
	Side to Side spacing	On hands and knees		○	●	○	○	○
	Shoulder volume spacing		Neither	○	●	○	○	○
	Spacing for deep breaths		Loose	○	○	●	○	○
	Brief Indexing							
	Front to Back spacing	Sitting		○	●	○	○	○
	Side to Side spacing	Bending over		○	●	○	○	○
	Vertical (crotch) spacing			○	○	●	○	○
	Glove Indexing							
	Fingertip spacing			○	○	○	●	○
	Finger crotch spacing			●	○	○	○	○
	Hand circumference spacing			○	○	●	○	○
	Overall Indexing							
	Shoulder-to-crotch length			○	○	●	○	○
Shoulder-to-heel length			○	○	○	●	○	
Heel-to-toe length			○	○	○	○	●	
				Ideal \longrightarrow Highly Obstructed				
PART 2	Field of View	Worst Position	Obstruction	0	1	2	3	4
	Side-to-side			○	○	○	●	○
	Up and down			○	○	○	○	●
	Vertical eye placement		NA	○	○	●	○	○
	Ability to see feet			○	○	●	○	○

Options to indicate specific regions or positions with issues

FEATURE ALIGNMENT

“Rate how well your body joints align with the suit’s soft goods breakpoints and joint bearings”

- Assessed by bearing/joint breakpoint


- Bearings:

- Shoulder
 - Thigh
 - Hip (some suits)


- Soft goods breakpoints:

- Elbow
 - Knee
 - Ankle
 - Hip (some suits)

- Ideally the suit’s bearings and natural breakpoints align with the body’s

FEATURE ALIGNMENT						
*Planetary suits only		Ideal  Worst Case				
Soft Goods Breakpoints	Break Point Location	0	1	2	3	4
Elbow Break Location	Bicep	●	○	○	○	○
Knee Break Location*	Thigh	○	●	○	○	○
Joint-Bearing Alignment	Alignment Location					
Shoulder Bearing	Shoulder centered	○	○	●	○	○
Hip Bearing*		○	●	○	○	○
Thigh Bearing*		○	○	●	○	○


Options to indicate alignment location



MOBILITY

“Rate how much your mobility is affected by your suit fit”

- Assessed by activities that stress range of motion:
 - Bending over
 - Reaching in front/overhead
 - Kneeling
 - Squatting
 - Sitting
- Difficult to distinguish between a suit *fit* issue and just a result of wearing a suit
 - But poor suit fit could definitely affect mobility
- This category may also be impacted by subject experience and may therefore need a different weighting to account for that

MOBILITY					
	Ideal  Worst Case				
Tasks	0	1	2	3	4
Bending over	⊗	○	○	○	○
Reaching in front	⊗	○	○	○	○
Reaching overhead	○	⊗	○	○	○
Kneeling	⊗	○	○	○	○
Squatting	⊗	○	○	○	○
Sitting	○	⊗	○	○	○

TEST DAY INFORMATION

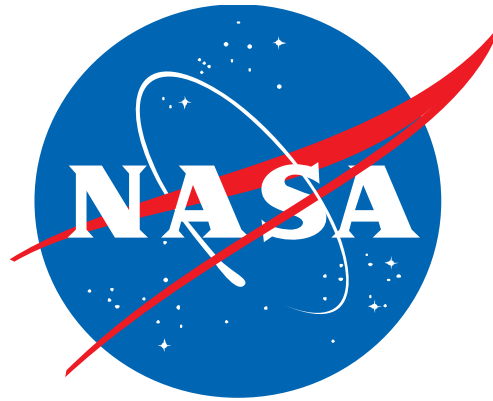
- Test conditions
 - Suit type
 - Gravity level
 - Offload environment
- Subject & STE info
 - Name/ID
 - Experience (hours)
- Experimental hardware
- General comments
- Preliminary fit questions
 - Allows subjects with a previous score to skip over unchanged sections
 - Improves speed of delivering survey

TEST DAY INFORMATION		
Survey Administrator <input type="text"/>		
Name of Test	<input type="text"/>	
Test Date	<input type="text"/>	
Test Point Type	- Select One -	
Suit Type	- Select One -	
Offload Environment	- Select One -	
Gravity Level	- Select One -	
If "other", please explain <input type="text"/> <input type="text"/> <input type="text"/>		
Is experimental hardware being used inside the suit? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		
If "yes", please explain (type, location, rigid/soft, dimensions, etc) <input type="text"/> <input type="text"/> <input type="text"/>		
Test Subject Number <input type="text"/>		
Spacesuit Experience - Select One -		
Experience in today's suit - Select One -		
STE Name <input type="text"/>		
STE Experience - Select One -		
Are there any other general comments or unique things about the suit sizing today? <input type="text"/> <input type="text"/>		
Preliminary Fit Questions (for those with prior suit fit check)		
Is anything about the suit abnormally uncomfortable?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
Is the suit tighter or looser anywhere than usual (indexing issues)?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
Are there obstructions to field of view that you haven't had before?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
Do any of the suit breakpoints/bearings feel abnormally positioned?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
Is there unusual difficulty maneuvering in the suit?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
Are there any unusual stability problems in the suit?	<input type="checkbox"/> Yes <input type="checkbox"/> No	
	Subject	Suit Engineer
	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No

CURRENT STATUS

- Primary focus so far
 - Which questions to ask
 - Wording of questions and scales
 - Identifying a rating scale that is simple and consistent
 - Basic layout
 - Gathering feedback from subjects and suit engineers
- Next steps
 - Transform survey from Excel into a database
 - Begin collecting pilot data from suited subjects
 - In collaboration with the EVA HHP Benchmarking study
 - Assess the logistics of how to deliver this survey
 - Detailed research version (time to deliver not important)
 - Operational version (less than 5 min, preferably closer to 2 min)
 - Multiple revisions still expected
 - Once finalized it will be analyzed for reliability and validity in repeated-measures testing
 - Suit sizing and fit study
 - Link with EIS suit exposure tracking data
 - Compare with objective suit fit measures being pursued concurrently

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